T1E1.4/95-103

Project: Standards project for network and customer interfaces associated with twisted pair transmission systems operating at maximum speeds in excess of 10 Mb/s.

Title: Simple Line Code System (SLC) for VDSL

Source

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Abstract: This contribution presents a solution for VDSL using a Simple Line Code (SLC) baseband binary line code, high performance baluns, and baseband isolation/restoration to allow POTS and bi-directional channels. The SLC system achieves 52 Mbps data rates over 750 feet of 24 gauge twisted pair with an NRZ binary line code and 1,000 feet using a non-NRZ binary line code. The SLC system is robust in the presence of narrow band interferers and emits levels of EMI well below accepted thresholds. The SLC system can be built from approximately 100 transistors. Very cost effective SLC modems can be developed without recourse to VLSI, and can therefore be produced soon.

**Simple Line Code VDSL Systems**

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## 1. Introduction

Tut Systems herein proposes a line code and system for consideration under the T1E1.4 study project for VDSL. The system comprises a class of transceivers Tut Systems designates Simple Line Code (SLC). Utilizing analog technology devised for very high speed twisted pair transmission for LAN, private line, and campus data communications, Tut SLC transceivers can transmit up to 52 Mbps over 1,000 feet of 24 gauge wire.

The principal benefits of SLC for VDSL are the lower complexity, by a considerable margin, over other candidate line codes, near term availability of cost effective products, and inherent robustness. While SLC has many significant benefits it is solidly grounded in physics and consequently has some limitations as well. It will not achieve the same distances theoretically realizable from more complex line codes, and SLC is less adaptive to narrowband interferers than other candidate line codes. The focus of SLC is on functionality, simplicity, availability and low power consumption. Tut therefore recommends that SLC be adopted for distances and environments it can realistically support. If future applications or more thorough analysis of the loop plant environment demand greater distances or operation under more harsh conditions, T1E1.4 should select a more complex line code to accommodate them. While a single line code would be desirable, market demand for low system costs and early implementation may favor a dual line code approach in this case.

Tut Systems bases its statements of performance below on system analysis and the experience gained from its Ethernet extension products using the same simple line code, which transmit 10 Mbps over 1500 feet of twisted pair in campus environments. Several thousand modems of this type have been successfully installed on many types of twisted pair wiring. Furthermore, Tut has built and demonstrated SLC transceivers operating at 52 Mbps downstream and 2 Mbps upstream, over POTS, at distances up to 400 feet of twisted pair.

## 2. Basic System and Simple Line Code

Tut Systems proposes two versions of its Simple Line Code[1]. As suggested by Figure 1, the first version, SLC-2, takes in binary NRZ data, shapes it to suit the line and channel separation requirements, and passes it through a hybrid circuit for transmission on the line. The receiver side accepts both the received signal and a residue of the transmit signal, filters out the transmitter residue and equalizes the line, then restores the dc content of the baseband signal lost in the transmitter. An output stage squares and re-times the received data stream. A POTS splitter divides modem signals from signals used for standard telephony. From there, signals are coupled to and from the transmission line.

[1]Tut's time-based modulator is the subject of certain intellectual property applications which have not been completed as yet. Until they have been completed and filed, Tut cannot disclose details of this modulation scheme without compromising coverage.

As an NRZ binary signaling system, SLC-2 requires bandwidth equal to half the data rate. However, it compensates by providing the most robust signal (binary) in the presence of noise. The second version of Tut's Simple Line Code, SLC-4, adds a time-based modulator to the system of SLC-2, halving the bandwidth required, and thereby stretching the distance achieved. The SLC codes can be extended further to SLC-16 and beyond to gain additional bandwidth reduction. As with all other line codes that transmit more than one bit per cycle, further bandwidth reduction is done at the expense of SNR for a given error rate. In environments where the noise is minimal, SLC-16 will make sense. However, in systems where the noise may be substantial SLC-2 or SLC-4 will be a more robust choice necessitating the resultant reduction in speed or distance.

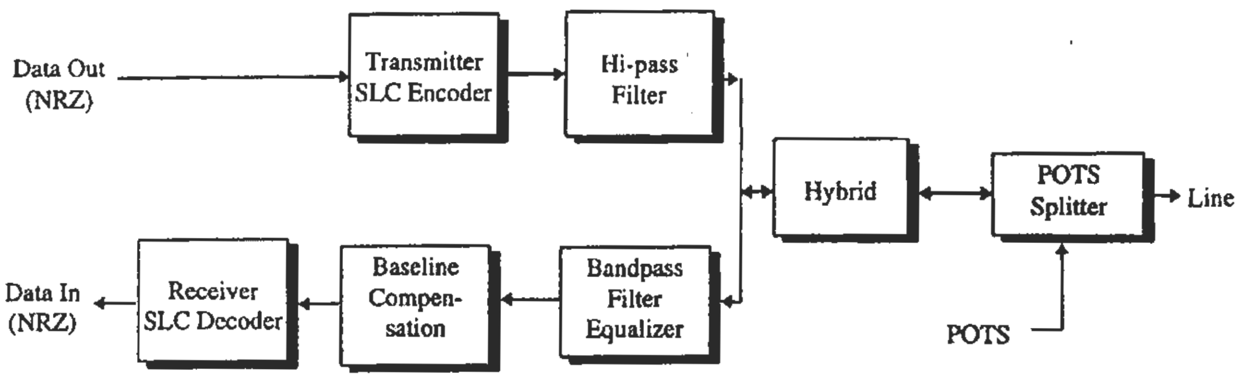


**Figure 1:** The figure depicts the basic block diagram of a SLC encoder.

SLC modems use an inherently baseband modulation system. Since VDSL modems must operate over POTS and provide bi-directional data paths, the Tut SLC system generates modulated signals in the baseband, filters out frequencies below a certain level, and then recovers these frequencies in the receiver by a method known as baseline compensation. In addition, this technique also separates upstream from downstream signals, frequency division multiplexing both channels as well as the POTS.

## 3. Transmission and performance parameters

Tut Systems' SLC-4 modems will achieve the following distances for two downstream data rates on the designated wire size:

| | | |
|---|---|---|
| 26 Mbps | 1,500 feet on 24 ga. UTP<br>1,000 feet on 26 ga. UTP | 6.5 MHz bandwidth |
| 52 Mbps | 1,000 feet on 24 ga. UTP<br>750 feet on 26 ga. UTP | 13 MHz bandwidth |

Tut Systems' SLC-2 modems will achieve the following distances for two downstream data rates on the designated wire size:

| | | |
|---|---|---|
| 26 Mbps | 1,000 feet on 24 ga. UTP<br>750 feet on 26 ga. UTP | 13 MHz bandwidth |
| 52 Mbps | 750 feet on 24 ga. UTP<br>500 feet on 26 ga. UTP | 26 MHz bandwidth |

For all systems described above, the following performance parameters apply:

| | |
|---|---|
| Upstream Rate | 2 Mbps |
| Line Impedance | 100 ohms |
| Transmit Power | < 24 dBm (-60 dBm/Hz) |
| Power Requirement (basic card) | < 500 mW |
| Latency | < 1 usec |